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Gadbois et al.

[11] **3,955,095**

[45] **May 4, 1976**

[54] **METHOD AND APPARATUS FOR DETERMINING THE AVERAGE SIZE OF APERTURES IN AN APERTURED MEMBER**

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[73] Assignee: **RCA Corporation,** New York, N.Y.

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[52] **U.S. Cl.** **250/550;** 250/572; 356/102

[51] **Int. Cl.**^{2} **G02B 27/38**

[58] **Field of Search** .... 356/106, 109, 107, 71; 350/162 R, 162 SF; 250/550, 556, 559, 571, 572

[56] **References Cited**

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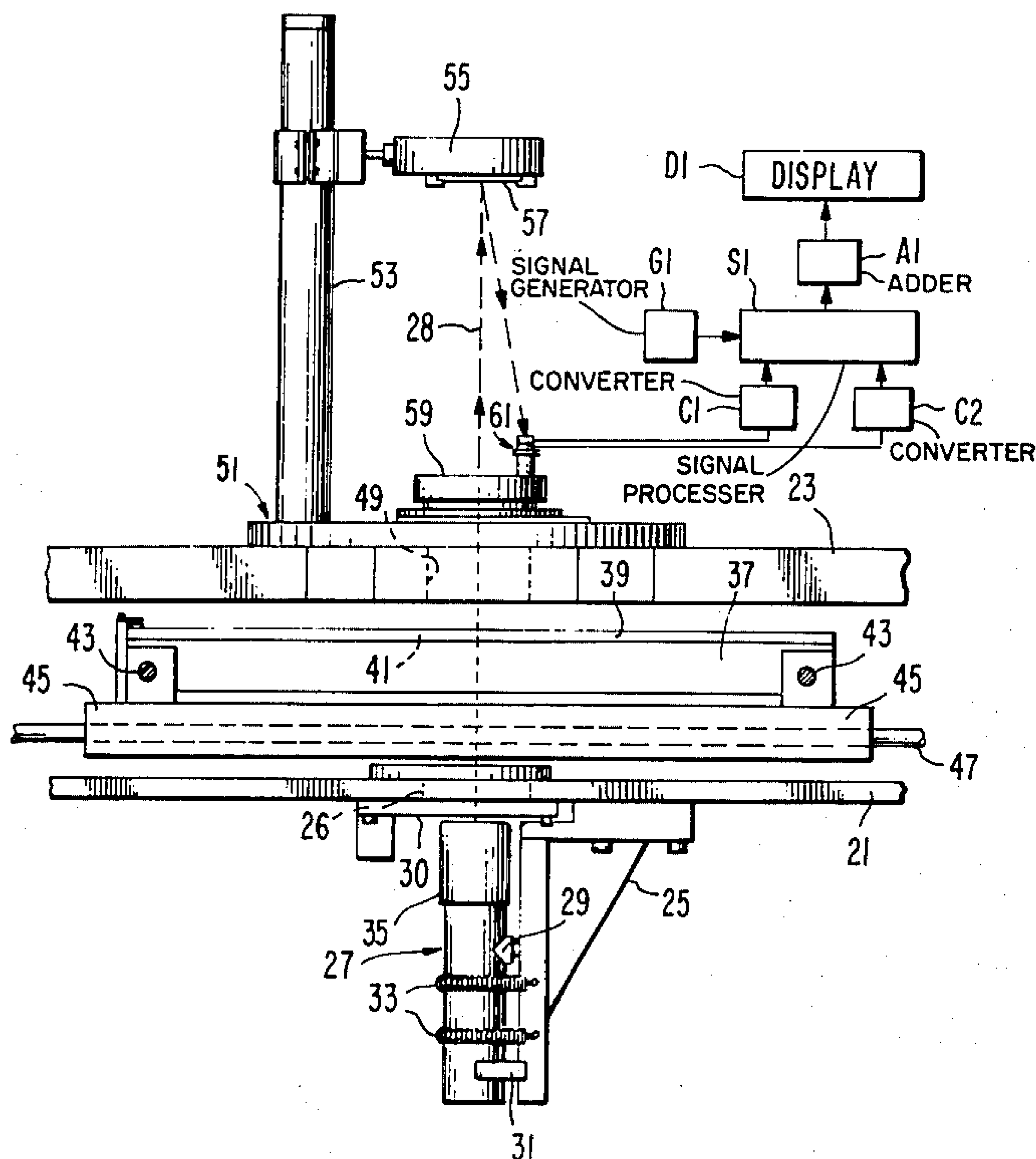
Primary Examiner—Archie R. Borchelt
Assistant Examiner—D. C. Nelms
Attorney, Agent, or Firm—Edward J. Norton; William Squire

[57] **ABSTRACT**

The average aperture width in a small area of an apertured member, such as a shadow mask for a cathode ray tube, is determined by passing a beam of substantially monochromatic light through an area of the member to form an interference pattern, detecting the intensities of at least two light fringes of the interference pattern, generating electrical signals which are representative of the detected intensities and then deriving the average width of apertures in the lit area of the members from the generated signals.

10 Claims, 4 Drawing Figures



DISPLAY
D1
A1 ADDER
SIGNAL GENERATOR G1
S1
CONVERTER C1
C2 CONVERTER
SIGNAL PROCESSER
55
57
53
28
59
61
51
49
23
39
37
43
41
45
47
26
30
21
25
29
35
27
33
31

Fig. 1

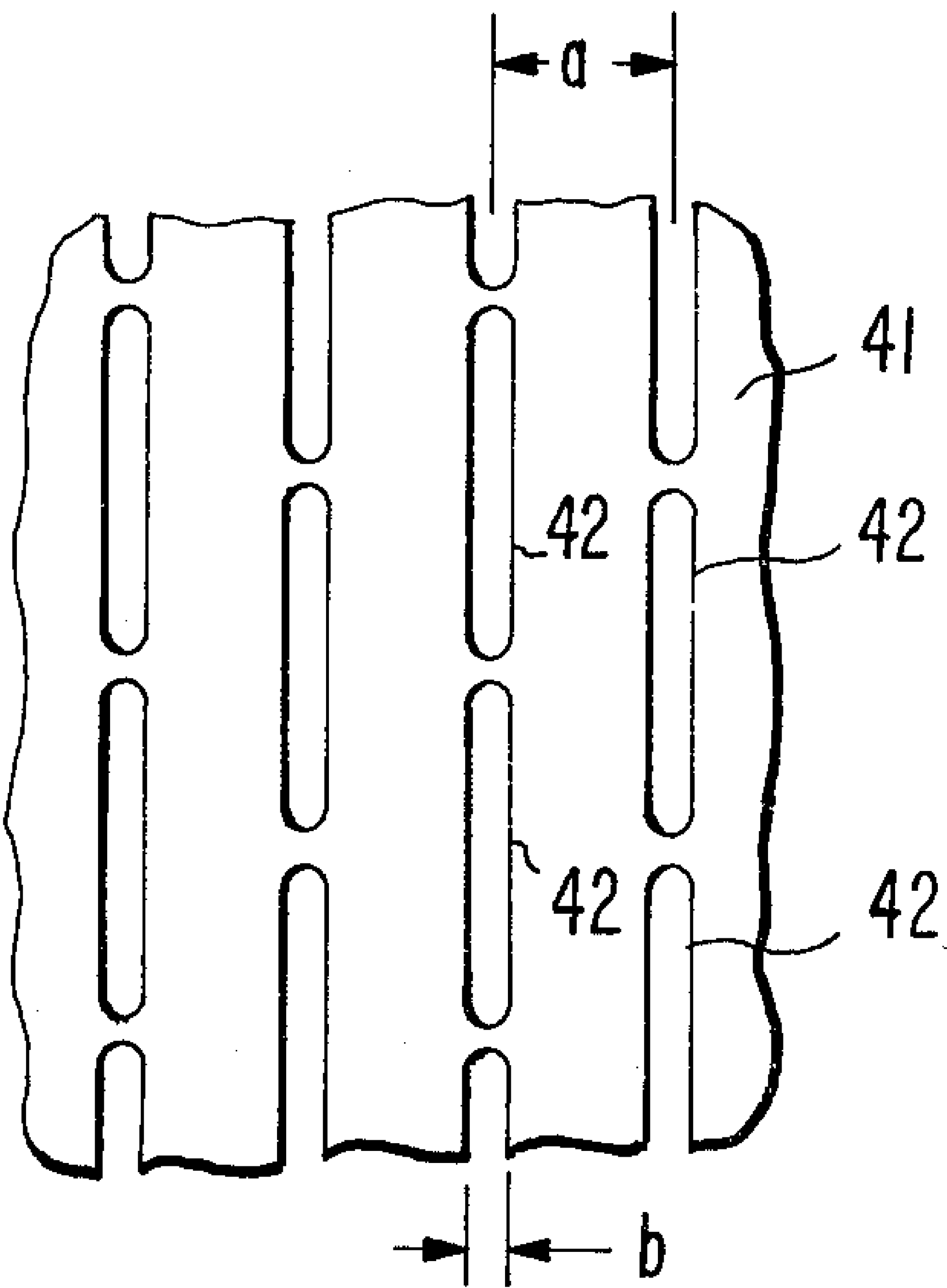


Fig. 2

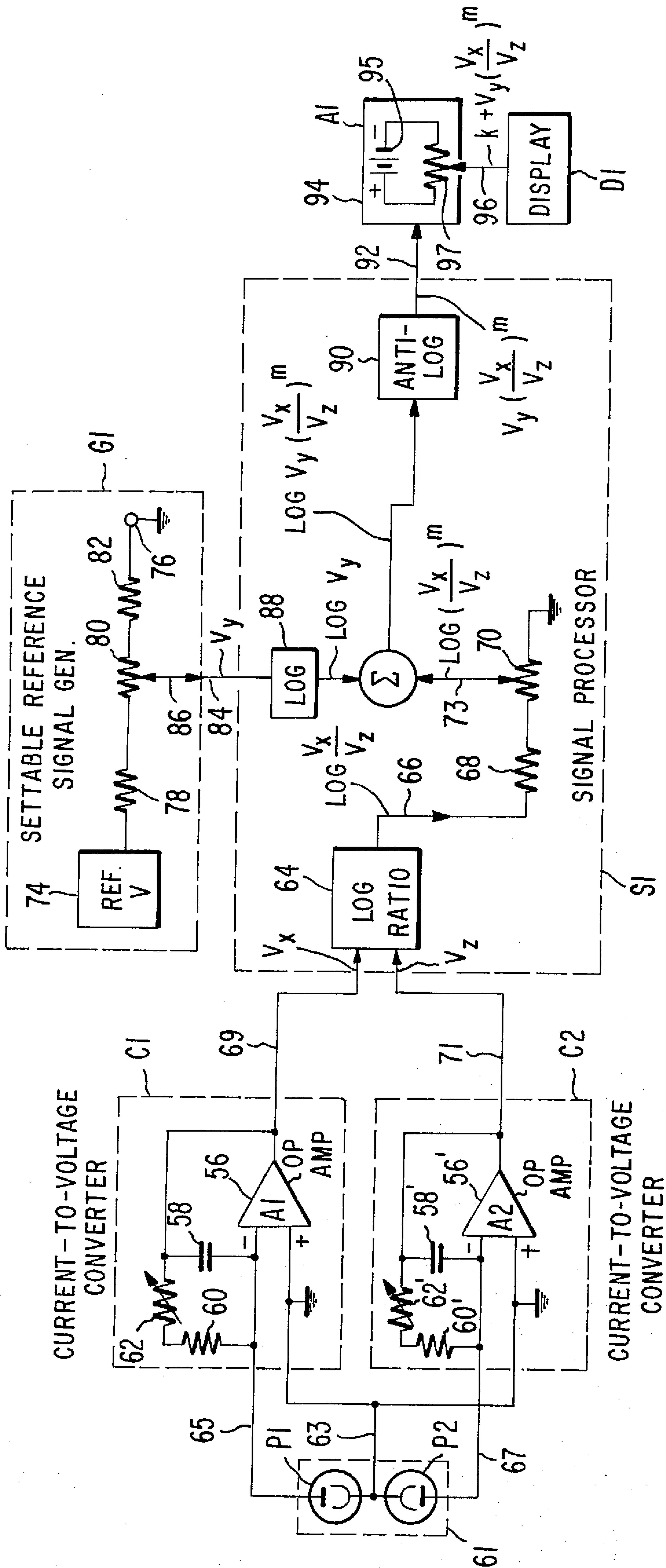
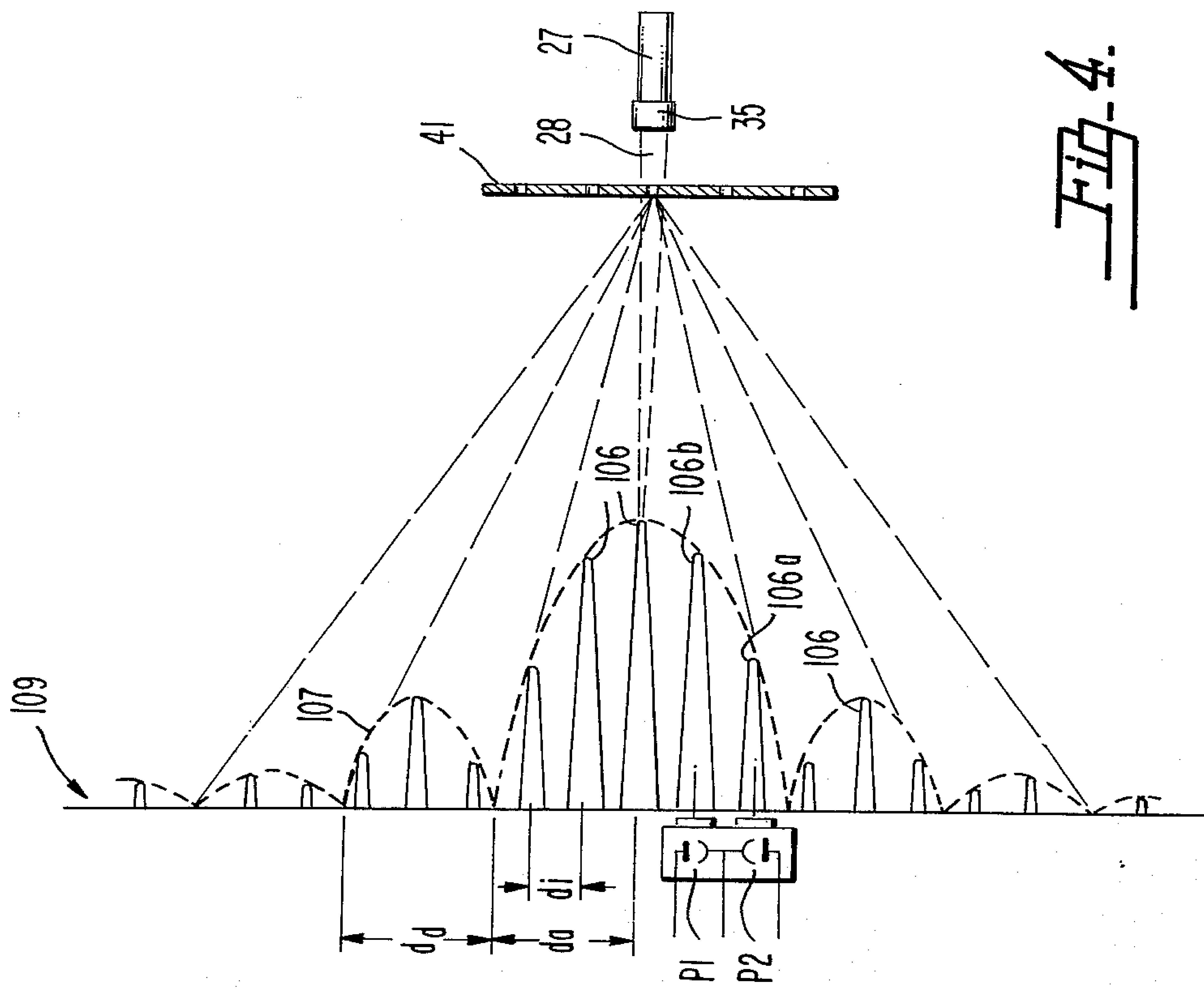


Fig. 3


27
35
28
41
106
106b
106a
106
107
109
di
da
dd
P1
P2
Fig. 4.

METHOD AND APPARATUS FOR DETERMINING THE AVERAGE SIZE OF APERTURES IN AN APERTURED MEMBER

BACKGROUND OF THE INVENTION

This invention relates to a novel method and apparatus for measuring the average size of a group of apertures in a member having an array of similar-sized apertures therein. The invention is especially applicable to measuring the apertures of an apertured mask for a cathode ray tube.

One type of color television picture tube employs a slit-type apertured mask. Such a mask is comprised of a metal sheet, about 4 to 8 mils thick (about 0.10 to 0.20 mm.), having an array of slits which are about 3 to 10 mils wide (about 0.075 to 0.25 mm.) whose center lines are substantially uniformly spaced about 20 to 80 mils (about 0.5 to 2.0 mm.) apart in parallel rows or columns. The slits may be of uniform width, or the widths may gradually become smaller from center to edge. The slits may be uniform, graduated, or random length in the rows, and are generally about 30 to 60 mils long. At least for quality-control purposes, it is desirable during manufacturing to check the widths of the slits from area-to-area on a single mask and also to check the widths of the slits from mask-to-mask.

It is known that projecting a beam of substantially monochromatic light from one side through an array of parallel slit apertures of substantially uniform widths and spacings produces combined interference and diffraction patterns in a plane spaced from the opposite side of the aperture array. The interference pattern is comprised of alternate light and dark bands of fringes. The diffraction pattern is an envelope defined by the peak intensities of the light fringes of the interference pattern. The envelope is also comprised of alternate light and dark bands including a central maximum and uniformly spaced side maxima (light bands) separated by minima (dark bands). The physical dimensions and spacings of the interference bands and diffraction bands are proportionately related to the average widths and spacings of the apertures which produce them. By prior methods, the average aperture width was derived by measuring one or more of these distances and then calculating the average width. Such prior methods are slow and the results are not as precise as is desired for quality control during mask manufacturing. Such prior methods do not lend themselves to automation by modern electronic techniques.

SUMMARY OF THE INVENTION

The novel method is based on the discovery that the average aperture width of an apertured member bears a specific relationship to the intensities of the light fringes constituting the combined interference and diffraction patterns produced by the member. This relationship can be closely approximated algebraically over a range of interest in a manner that allows the average aperture width to be calculated rapidly and accurately by electronic techniques.

The novel method comprises projecting a beam of substantially monochromatic light through a plurality of apertures in a relatively small area of an apertured member to produce a combined interference and diffraction pattern. Then, the intensities of two light fringes of the interference pattern, preferably in the central maximum of the diffraction pattern, are sensed.

Electrical signals are then generated which are a function of the intensities of the sensed fringes. The generated electrical signals are then processed in accordance with the relationship.

$$\bar{b} = k + V_y R^m$$

wherein $\bar{b}$ represents the average aperture width, R has a value representing the ratio of said generated electrical signals and k, V_y and m have values corresponding to a given mask.

A novel apparatus for determining average aperture width includes means for projecting a beam of monochromatic light through a plurality of apertures in an apertured member to produce a combined interference and diffraction pattern. Means are included which are responsive to the pattern for generating a signal therefrom which is representative of the average aperture width. The generating means includes signal processing means responsive to two signals representing two respective intensity fringes for producing an output signal having a value represented by the relationship

$$\bar{b} = k + V_y R^m$$

where $\bar{b}$ represents the average aperture width of said plurality of apertures, R has a value representing the ratio of the value of said two signals and k, V_y and m have values corresponding to a given mask.

In one form of the invention, a low-power laser beam or other source of monochromatic light in a fixed position projects a beam through the apertured member upon two photocells which are in fixed positions with respect to one another and fixed distances from the member. In a preferred form, the beam is so refracted as to focus the beam upon the photocells, each of which generates an electrical signal in response to the incident light. The member may be stationary or moving linearly when the reading is made since the pattern remains stationary irrespective of translational motion of the work piece. The light beam may vary in intensity or brightness, due, for example, to variations in line voltage. However, the ratio of the intensities of one measured fringe to the other remains constant. With a simple electronic processing circuit, the average width of the apertures within the beam is derived from the generated electrical signals. The derived signal may be used to actuate some automatic process or may be employed to actuate a display of the aperture width.

Only the average width of the apertures is a varible in any particular apparatus setup. The center lines of the rows of the apertures within the beam are substantially uniformly spaced. The wavelengths of light of the beam are fixed by the choice of the source. The spacing of the work piece to the pattern plane is fixed by the design and adjustment of the equipment. A variation in the average slit width results in a variation in the ratio of the intensities of the interference fringes, which fringes are fixed in position in the plane of the photocells with respect to one another and with respect to the center line of the light beam by the adjustment of the equipment.

If, in the apertured member, the center-to-center spacing between adjacent apertures varies substantially, the position of the fringes will shift and cause an apparent change in aperture width. Additional detectors can be used to sense the change in fringe position and can compensate the aperture width output as well as being used to indicate the extent of the shift. This allows measurement of masks when the aperture spac-

ing is not constant.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a partially-schematic fragmentary front view of a novel apparatus for carrying out the novel method.

FIG. 2 is a fragmentary plan view of a mask having an aligned array of slit apertures therein.

FIG. 3 is a diagram of a circuit used with the apparatus of FIG. 1.

FIG. 4 is a schematic diagram used to explain some of the optical effects used to carry out the method of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 shows a lower frame **21** and an upper frame **22** mounted in fixed relation to one another by means that are not shown. The bottom side of the lower frame **21** carries a laser mounting bracket **25** on which is mounted a helium-neon laser tube **27** which is held in two guides **29** and **31** by two springs **33.** A ten-power converging lens in a lens holder **35** is mounted on the output side of the laser tube **27** so that a light beam **28** from the laser tube **27** may be projected upward through the lens in a manner that avoids destructive effects to persons working in the area. Any monochromatic light source may be used in place of the particular laser tube **27.** A lower-power helium-neon laser is preferred because of its relatively low initial cost, low cost of operation and relatively high safety. The lens may be of any convenient size, power and optical characteristic capable of producing a light spot of the desired size in the plane of the apertured mask to be measured and also a focused spot in the plane of the detector **61** described below.

The lower frame **21** has an opening **26** therein to permit the light beam **28** from the laser tube **27** to pass upward therethrough and carries a shutter **30** for intercepting or passing the beam **28** as desired. The top side of the lower frame **21** supports a mask carrier **37** and means for guiding the movement thereof in a generally horizontal plane, normal to the path of the light beam. The carrier **37** includes removeable insert **39** having an open portion adapted in shape and size to receive an apertured mask **41** to be measured. The carrier **37** may be moved in one direction (designated the y direction) on two "*y*" guide rods **43** on two supports **45.** The supports **45** may be moved in the other direction (designated the *x* direction) on two "*x*" guide rods **47** supported on the lower frame **21** in a manner not shown. The arrangement of "*x*" and "*y*" guide rods **43** and **47** permits the apertured mask **41** in the carrier **37** to be translated rapidly through the beam **28** to measure different areas on the mask.

The top portion of the upper frame **23** supports a light-tight box (not shown) in a position roughly centered over the laser tube **27** and a crossplate **51.** The upper frame **23** has an opening **49** therein to permit the light beam **28** from the laser tube **27** to pass upward therethrough. A vertical mounting post **53** supported by the crossplate **51** carries a first adjustable support **55** and a plane mirror **57** thereon. A second adjustable support **59** carrying a fringe detector **61** thereon is supported on the crossplate **51.** In operation, the supports **55** and **59** are adjusted for the mirror **57** to receive and reflect light from the laser tube **27** to the fringe detector **61.**

The fringe detector **61** comprises two photocells **P1** and **P2** in a single container a known distance apart and is used to detect simultaneously two different fringes of an interference pattern. Of course, photocells in separate containers may be used. More than two photocells may be used. The outputs of the fringe detector **61** are fed to a circuit system, which is described in greater detail with respect to FIG. **3,** comprising two current-to-voltage converters **C1** and **C2,** a settable reference-signal generator **G1,** a signal processor **S1** and an "add-*k*" circuit **A1.** the circuit system derives the desired width dimension and then displays it numerically on a display **D1.**

FIG. 2 shows a fragment of an apertured mask **41** having a plurality of slit apertures **42** arranged lengthwise in columns and spaced apart a uniform center-to-center spacing "*a*" with respect to the next adjacent column of apertures. The apertures ideally should have identical widths "*b*". In producing the apertured mask **41,** the center-to-center aperture spacing "*a*" is, by the nature of the manufacturing process, fixed for a given apertured mask. there is negligible variation of the center-to-center spacing "*a*" from one apertured mask to another. However, the apertures are produced by a process wherein the slit widths "*b*" may vary substantially in the same mask and from mask-to-mask. Therefore, it is important to be able to ascertain the average width "*b*" of a plurality of apertures **42** over small areas in a given apertured mask.

The present invention takes advantage of the fact that when a monochromatic light beam is projected through an array of apertures, an interference pattern is formed wherein the ratio of the intensities of two fringes of the pattern preferably adjacent fringes in the central maximum, is a function of the average aperture width of the area illuminated. It can be shown that the average width $\bar{b}$ is defined by the polynomial equation

$$\iota = \alpha + \mathbf{BR} + \sqrt{\ }\,\mathbf{R}^2 + \ldots\ldots \delta R^n \qquad (1)$$

where R is the ratio of the intensities. A good approximation of this relationship is

$$\bar{b} = k + V_y R^m \qquad (2)$$

where k, V_y and m are preselected values that are determined empirically for each type of mask. These values are determined for each mask type. Such determinations are within the abilities of one skilled in this art. By type of mask is meant a mask having distinctive aperture size range, aperture spacings or other characteristics which have a substantial effect on the values of k, V_y and m.

In the circuit system shown in FIG. **3,** the two outputs of photocells **P1** and **P2** representing the intensities of two fringes of the interference pattern are used to produce signals V_x and V_z in the current-to-voltage converters **C1** and **C2** respectively. The circuit then derives the average aperture width b according to the relationship

$$\bar{b} = k + V_y (V_x / V_2)^m$$

where k, V_y and m are preset values for each type of mask or other apertured member. The output is then applied to a suitable display **D1,** which may be a commercially available digital panel display apparatus. The display **D1** includes an analog-to-digital converter and

a digital display device for displaying the magnitude of the analog signal applied as an input thereto.

The converters C1 and C2 are substantially identical and therefore a description of only one will be provided. The same numbers with and without the primes refer to similar parts in converters C1 and C2. Converter C1 is comprised of an operation amplifier **56** and a filtering capacitor **58** in parallel with serially-connected resistances **60** and **62** connected between the output and the inverting input of the amplifier **56.** The noninverting input of amplifier **56** is connected to a point of reference potential such as ground. The values of the resistances **60** and **62** determine the gain of the operation amplifier **56.** The resistance **62** is variable for adjusting the output voltage on the outp9ut lead **69** within a desired range suitable for use with the signal processor **S1.** The capacitor **58** serves as a low pass filter for filtering out instantaneous changes in intensity in the light source. The output signal V_x on the output lead **69** of converter C1 is a signal whose voltage amplitude represents the intensity of the light received by the first photocell **P1.** In a similar manner, the voltage amplitude of the signal V on output lead **71** from converter C2 represents the intensity of the light received by the second photocell **P2.**

The output leads **69** and **71** are connected to the input of the log ratio device **64** which forms a part of the signal processor **S1.** The log ratio device **64** produces a signal whose voltage magnitude is representative of the logarithm of the ratio of the amplitude of the signal $V_x$with respect to the amplitude of the signal V_2. The output of the log ratio device **64** is applied through a lead **66** to a serially-connected resistance **68** and variable reistance **70** and then to a summation device **72** through a first wiper arm **73.** The values of the resistances **68** and **70** determine the value of the exponent "m", the power to which the ratio V_x/V_z is raised.

A reference-signal generator G1 includes a source of a reference voltage **74** whose output is connected to a reference potential such as ground at a terminal **76** through voltage-dividing resistors **78, 80** and **82.** A second wiper arm **86** on the resistance **80** is connected to the output lead **84** of the generator G1. The setting of the second wiper arm **86** determines the value of the generated signal V_y appearing on the lead **84.**

The lead **84** is connected to the signal-processor summation device **72** through a logarithm device **88** which produces the logarithm of the value of the amplitude of signal V_y. The summation device **72** produces a signal representing the sum of the logarithm of signal V_y and the logarithm of the ratio of signals V_x/V_z raised to the m power, or log V_y $(V_x/V_z)^m$. This signal is applied as an input to an antilog device **90** which provides a signal whose amplitude represents the antilog of the signal applied to the input thereof. The output signal of the antilog device **90** is applied along lead **92** connected to an adder device **A1,** which adds the value "*k*" to the signal-processor output. The adder device **A1** is comprised of a voltage source **95** and a variable resistor **97** in parallel. A third wiper arm **96** (whose position determines the value of "*k*") of the variable resistor **97** is connected to a suitable analog-to-digital converter and digital display device **D1.**

The log ratio device **64,** the antilog device **90,** the logarithm device **88,** the summation device **72** and the reference voltage source **74** are commercially available devices. Such devices are manufactured in a single multifunctional module; for example, model number 433J manufactured by Analog Devices, Inc. of Norwood, Mass. A description of that device is provided in a catalog C125-10, dated May 1972 and published by Analog Devices, Inc.

In setting up the apparatus for operation, the height of the platform **55** above the crossplate **51** is set to give the desired fringe spacing at the detector **61.** In one example, the light path from the holder **39** to the detector **61** is about 60 inches and the centers of the photocells **P1** and **P2** are about 0.054 inches apart. The outputs of the converters **C1** and **C2** are adjusted so as to be substantially equal with equal amounts of light incident on the photocells **P1** and **P2.** This can be accomplished by suitable display means, such as display **D1,** temporarily coupled directly to the leads **69** and **71** by means not shown. The circuit for the signal processor **54** described above is responsive to voltage inputs along the leads **69** and **71** having a value in the range of **0** to **10** volts. The outputs of the converters **C1** and **C2** are adjusted by adjusting the resistances **62** and **62'** respectively. With no mask **41** in place and equal amounts of light on the photocells **P1** and **P2,** the signals V_x and V_z are matched. Then, a mask **41** is placed in the mask holder **37** and a beam **28** is passed through the mask. The lens in the holder **35** is adjusted to focus the beam on the detector **61,** and the detector **61** is positioned in the focused beam so that the desired fringes are detected and so that the value of V_z is greater than the value of V_x.

Three standard aperture masks of the same type whose aperture widths *b* are maximum, bogie and minimum, respectively, (as predetermined by precise measurements in a measuring microscope or the like) are provided. The mask with maximum aperture size is first inserted in the measuring light beam **28.** The third wiper arm **96** is now positioned so that a correct reading is shown on the display **D1.** Next, the mask with minimum aperture size is inserted into the beam **28.** The second wiper arm **86** in the settable reference signal generator **G1** is positioned so that a correct reading of the hole size appears on the display **D1.** Next, the mask with the bogie aperture size is inserted in the light beam **28** and the first wiper arm **73** of the resistor **70** is positioned so that a correct reading appears on the display **D1.** With the first, second and third wiper arms **73, 86** and **96** so positioned, which determines the values of m, V_y and k, respectively, the procedure is repeated to position these wiper arms more precisely so that a proper reading appears on the display for each of the three standard masks inserted in the light beam **28.** The positions of the three wiper arms **96, 86** and **73** is noted and these values can be used whenever masks of the same type are to be measured. A similar setting up procedure is employed for each type of mask.

To operate the apparatus of FIGS. **1** and **3,** a mask **41** with slit-shaped apertures therein is placed in the holder **39.** The mask may be a flat, etched sheet prior to being formed into the domed shape for use in a color television picture tube. However, the apparatus may also be used with a formed mask. The laser tube **27** is turned on so that the beam **28** is projected upward and a proper positioning of the three wiper arms **96, 86** and **73** is made in accordance with the positions noted for that type of mask. The mask holder **39** is slid into a desired position on the "*x*" and "*y*" guides **43** and **47** and the average aperture width for the area illuminated by the beam appears on display **D1.** The mask holder **39** may be moved to different positions to measure the

average widths of apertures at different areas of the mask. Then the mask may be removed from the holder, a different mask of the same type is inserted therein and the measurement process repeated.

FIG. 4 illustrates in simplified form what happens in the optical system as the beam **28** passes from the laser tube **27** through the apertured member **41** to the detector **61.** The laser tube **27,** a 5-mw HeNe laser, is fitted with a lens system that expands the laser beam and then focuses the expanded beam in the plane **109** of the detector **61.** By changing the power of the lens system, the beam size can be changed in order to change the number of mask apertures in the measurement. In one system, a ten-power magnification lens produces a beam that is about one-half inch in diameter where it passes through the mask **41.** The intensity across the beam **28** has nearly a Gaussian distribution; consequently the apertures near the center of the beam transmit more light than those near the edges of the beam and have a stronger influence on the measurements. The mask **41** is placed so that the beam impinges on the mask **41** perpendicular to its surface. As the beam strikes the mask **41,** diffraction occurs and the fringes **106** of an interference pattern can be observed in the detector plane **109,** which is placed at a convenient distance from the apertured mask **41.** The greater the distance, the greater the spacing of the fringes of the interference pattern. The fringes **106** are substantially uniformly spaced a distance d_i apart. The detector **61** is positioned to receive two adjacent light fringes **106***a* and **106***b* on the two photocells P1 and P2, respectively. In FIG. **4,** the brightness of fringes is indicated by the horizontal distance of the curve **106** from the detector plane **109.** With the light source focused in the plane **109** of the detector **61,** the pattern appears stationary even when the mask **41** is moved linearly. Rotation of the mask will cause the pattern to rotate in the plane **109,** but it will remain centered on the same axis.

Also in FIG. **4,** there is shown an envelope **107** defined by the peaks of the fringes **106,** which defines a diffraction pattern. The diffraction pattern comprises a central maximum and side maxima. The distance d_i between the peaks of the fringes **106** is an inverse function of the distance between rows of apertures in the mask **41.** The width d_d of a side maximum equals the half width d_o of the central maximum of the diffraction pattern and are inverse functions of the aperture width. The relative height or intensities of the various fringes **106** of the interference pattern are determined by aperture width.

The novel device provides fast, accurate and reliable means of measuring the sizes of shadow-mask apertures. The device was developed primarily for measurement of slit widths in flat, slit-type shadow masks. It has shown a capability for measuring webs (the distance between the ends of two slit apertures in a row) and can be extended to measure apertures in formed masks and masks having round apertures as well as mask masters. Some advantages of this method over previously employed methods (transmission and microscope) are

1. improved accuracy,
2. faster speed of measurement, and
3. improved ability to average a large number of apertures or to measure individual apertures with the same operating speed.

What is claimed is:

1. A method for determining the average aperture width of a portion of an array of apertures in an apertured mask for a cathode ray tube, said method comprising:

a. projecting a beam of substantially monochromatic light through a plurality of apertures in said portion of said mask to thereby produce a combined light interference and diffraction pattern containing aperture width information,

b. detecting the intensities of at least two fringes of said pattern,

c. generating separate electrical signals which are representative of said detected intensities, and

d. processing said generated electrical signals in accordance with the relationship

$$\bar{b} = k + V_y R^m$$

where $\bar{b}$ represents the average aperture width, R has a value representing the ratio of said generated electrical signals and k, V_y and m have values corresponding to a given mask.

2. The method of claim **1** wherein said processing step includes:

providing signals representing the values of the logarithms of the values corresponding to the terms R^m and V_y,

summing the values of said logarithm signals,

providing a signal having a value representing the antilogarithm of said summed logarithm signals, and

adding a signal having a value representing the term k to the value of said antilogarithm signal.

3. The method of claim **2** further including the step of displaying the value of said width.

4. A method for determining the average aperture width in a portion of an array of apertures in an apertured mask for a cathode-ray tube, said mask having two opposite major surfaces, said method comprising:

a. projecting a beam of substantially monochromatic light from a source spaced from one of said major surfaces through a plurality of apertures in adjacent rows of said portion of said mask,

b. focusing said beam in a plane spaced from the other of said major surfaces of said mask to thereby produce a combined light interference and diffraction pattern in said plane,

c. detecting the intensities of at least two interference fringes of said diffraction pattern, the ratio of said intensities being a function of the average width of said plurality of apertures,

d. producing from said detected intensities an electrical signal which is representative of the ratio of said intensities, and

e. processing said produced electrical signal to provide an electrical output signal having a value manifesting the average width of said plurality of apertures, said processing step including producing a signal having a value represented by the relationship

$$b = k + V_y R^m$$

where b represents the average aperture width of said plurality of apertures, R has a value representing the ratio of the value of said intensities and V_y, k and m have values corresponding to a given mask.

5. The method of claim **4** further including the step of displaying the value of said average aperture width.

6. The method of claim **4** wherein the detected fringes include the two adjacent fringes on one side of the central maximum of said pattern.

7. An apparatus for determining the average aperture width of a portion of apertures in an apertured mask comprising:
- means for projecting a beam of substantially monochromatic light through a plurality of apertures in said mask to produce a combined light interference and diffraction pattern containing aperture width information,
- means responsive to said pattern for providing at least two signals each representing a separate, different corresponding respective intensity fringe of at least two fringes of said pattern, and
- means responsive to said two signals for generating an electrical output signal therefrom representing the average width of said plurality of apertures, said output signal generating means including signal processing means responsive to said two signals for producing an output signal having a value represented by the relationship

$$\overline{b} = k+V_y R^m$$

where $\overline{b}$ represents the average aperture width of said plurality of apertures, R has a value representing the

ratio of the value of said two signals and k, V_y and m have values corresponding to a given mask.

8. The apparatus of claim 7 further including means responsive to said output signal applied as an input thereto for displaying said average aperture width.

9. The apparatus of claim 7 wherein said mask is a cathode-ray tube mask and said apertures are slits.

10. The apparatus of claim 7 wherein said processing means includes
- means responsive to said generated electrical signals for providing signals representing the values of the logarithms of the values corresponding to the terms R^m and V_y,
- means responsive to said signal providing means for summing the values of said logarithm signals applied as an input thereto,
- means responsive to said summing means for providing a signal having a value representing the antilogarithm of said summed logarithm signals applied as an input thereto, and
- means for adding a signal having a value representing the term k to the value of said antilogarithm signal.

* * * * *

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 3,955,095

DATED : May 4, 1976

INVENTOR(S) : George Simon Gadbois and Frank Rowland Ragland, Jr.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 5, add the following:

-- Cross References to Related Applications
This application is related to application Serial No. 512,135 filed October 4, 1974, having the same title as the instant application, invented by Frank Rowland Ragland, Jr., and assigned to the assignee of the present invention.--

Column 4, line 38 change "$\iota = \alpha + BR + \sqrt{R^2 +} \ldots\ldots \delta R^n$" to read

-- $\bar{b} = \alpha + BR + \psi K^2 + \ldots\ldots \delta R^n$ --

Column 4, line 57 change "$\bar{b} = k + V_y (V_x / V_2)^m$" to read

--$\bar{b} = k + V_y (V_x / V_z)^m$--

Column 5, line 15 change "outp9ut" to read --output-- (second occurrence)

Column 5, line 31 change "V_2" to read --V_z--

Column 8, line 59 change "$b = k + V_y R^m$" to read --$\bar{b} = k + V_y R^m$--

Column 8, line 60 change "b" to read --$\bar{b}$--

Signed and Sealed this

[SEAL] Thirty-first **Day of** August 1976

Attest:

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